Extremely large refractive indexes in anodic tantalum pentoxide

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Tantalum oxides are desired for numerous applications, as discussed in [1]. The material itself has been studied for rather a long time, and much useful information regarding it can be found in [2] and its references.

Here we present extremely large refractive indexes observed in the wavelength range 455nm to 531nm in some anodic tantalum pentoxide samples.

Thin tantalum layers were deposited on BK7 glass in an e-beam system. The anodic oxidation of the tantalum layers was conducted in H_2SO_4 (0.05%) electrolyte at 23°C in a cell, as previously described in [3]. Ellipsometric studies were conducted in the wavelength range 246nm to 1679nm (with a resolution of 1.7nm) using a J. V. Woollam Co., Inc., Spectroscopic Ellipsometer, VASE. The complex reflection coefficient *versus* λ was optimized using the same routine for all samples and provided values of n, k, and α. Some extreme n and large α values were obtained for some samples in the wavelength range 455nm to 531nm. Values of n and α, as functions of λ, for one sample are shown in Figure 1, for which a maximum n value of 484.8 (in the figure the range of n values only goes up to 10), with a corresponding α of $1.11x10^3 cm^{-1}$, was obtained at λ=495nm. Table 1 shows 8 extreme and 2 large n values measured in the wavelength range 455nm to 531nm.

The extreme values probably result from small polycrystalline clusters dispersed in amorphous tantalum pentoxide. The presence of these crystalline clusters was discussed in [4]. Such clusters usually are not charge neutral, therefore, they can interact with electric fields, such as incident light. The energies of these cluster related fields are estimated to be in the range 0.0125eV to 1.25eV [5]; for pyramidal TaO(5) the energy is 0.101eV [6]. Our estimated energies for the extreme cases are in the range 0.0104eV to 0.0446eV. However, for the two samples for which the peak n values were 9.6 and 23.0, the estimated energies were much higher and matched 3s Ni [7] and 2s O [8], respectively, in possible NiO OH impurities.

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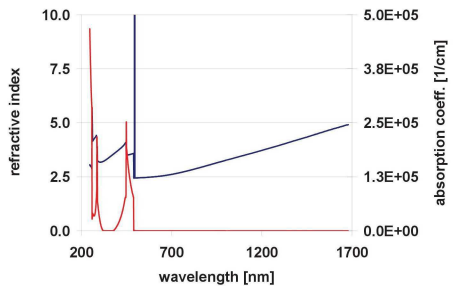

Figure 1. The refractive index (left axis, blue curve) and the absorption coefficient (right axis, red curve) as functions of wavelength for one of the samples studied (sample #3). For this sample, at λ=494.5nm the refractive index is 484.8 and the absorption coefficient is1.11E+3cm^{-1}.

sample #	λ [nm]	n	α [cm^{-1}]
1	454.6	869.4	5.14E+6
2	480.1	945.6	1.67E+4
3	494.5	484.8	1.11E+3
4	494.5	969.6	2.97E+4
5	494.5	1000.0	3.02E+4
6	496.1	843.9	1.88E+5
7	497.6	23.0	2.53E+5
8	497.6	824.0	2.09E+5
9	504.0	725.7	1.33E+6
10	531.1	9.6	3.02E+4

Table 1. Refractive indexes and absorption coefficients, at specific wavelengths, for ten samples exhibiting extreme, or large, n values.